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HISTORY OF THE MK 5 WARHEAD (u)

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TIMETABLE OF MK 5 WARHEAD EVENTS

1900	Rocketry has beginnings as a science.
1929	Nazis start intensive study of guided missiles.
Early 1946	Rand Project founded. Early rocket-study work.
3-46	Army Air Forces institute work on Project MASTIFF, an experimental missile.
1-10-47	Early proposals for atomic warheads.
4-29-49	Division of Military Application requests views of Military Liaison Committee on missile/atomic warhead work.
1-27-50	Detailed studies of missile/atomic warheads approved.
6-21-50	Sandia Weapons Development Board accepts cognizance of missile/warhead work.
10-1-50	Department 1270 established at Sandia for missile/warhead design.
9-11-51	Military characteristics for XW-5 Warhead issued.
8-53	Mk 5 Mod 0 Warhead design released.
7-54	Mk 5 Mod 0 Warhead enters production.

<u>Mk 5/REGULUS</u>

1-50	Project approved by Secretary of Defense.
1-51	Missile/warhead placed in active design.
9-10-51	XW-5/REGULUS Ad Hoc Working Group meets.
8-18-52	RAM Project initiated.
10-28-52	Flight tests of XW-5/REGULUS started.
9-53	Design release of Mk 5/REGULUS.
4-54	Initial production of Mk 5/REGULUS.

Mk 5/MATADOR

Early 1950	Missile considered for marriage with atomic warhead.
12-18-50	Project approved by Joint Chiefs of Staff.
10-3-51	XW-5/MATADOR Ad Hoc Working Group formed.
Early 1952	Missile flight problems develop.
Spring 1954	Black Swan program initiated.
Early 1956	Continuing missile difficulties cause cancellation of program.

Mk 5/RASCAL

3-16-50	Military Liaison Committee proposes XW-5/RASCAL marriage program.
8-20-50	Sandia Weapons Development Board authorizes program activity.
11-7-51	XW-5/RASCAL Ad Hoc Working Group formed.
1-53	Fuzing responsibility for project assigned to Air Force.
Fall 1953	Missile flight problems develop.
3-56	Program canceled in favor of Mk 27 Warhead.

Mk 5/RIGEL

8-28-50	Field Command informs Sandia concerning project.
4-25-51	Missile characteristics issued.
9-30-53	Program canceled.

XW-5/HERMES

3-13-51	Army suggests use of HERMES proximity fuzes on atomic warhead installations.
5-21-51	HERMES temporarily deleted from program.

5-27-52	HERMES reinstated; to be mated to Mk 5 Warhead.
10-16-52	Budget cuts delay program.
9-18-53	Program terminated.

<u>Mk 5/F-101</u>

4-9-53	Program established by Joint Chiefs of Staff.
8-53	XW-5/F-101 Joint Project Group formed.
3-56	Program canceled.

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Figure 1. Mk 5 Warhead

CHAPTER I

Mk 5 MISSILE-WARHEAD PROGRAM

The first recorded use of rockets in military operations is ascribed to the Chinese, who were employing these items (the forerunner of our Independence Day fireworks) as early as the year 1232 when the Mongols attacked the Tartar city of Kaifeng. Within the same century, rocket knowledge spread to Europe. Use of these devices as offensive weapons continued sporadically through the years, with our own National Anthem noting the "rocket's red glare" of the British bombardment of Fort McHenry in 1814.

The Russians began a serious study of rocketry in the early 1900's, which was paralleled by the work of Robert H. Goddard of Clark University, Worcester, Massachusetts. Professor Goddard was operating a rocket engine in 1914, delivered an operational rocket to the United States Army in 1942, and predicted the possibility of trips to the moon.

Goddard's efforts were largely unappreciated in his own country. The Germans, in the 1920's, avidly studied his work and developed an advanced rocket science, acting under the incentives of the disarmament rules laid down after World War I, which prevented Germany from possessing obvious implements of war, but permitted work on gliders, mobile means of shifting large bodies of troops, and rockets. These latter items were deemed by the Western world to be somewhat infantile, worthy only of the attention of Buck Rogers, a cartoon character whose space exploits have since been almost surpassed by reality.

By the mid-1920's the Germans were firing experimental rockets, and in 1929 they embarked on an accelerated and well-funded guided-missile and rocket program. Shortly thereafter, the Russians (under Soviet domination) also began firing an extensive series of atmospheric research rockets, and by 1935 they were regularly reaching altitudes of 30,000 feet--four times that attained by Goddard at the time.

With the approach of World War II, both the German and Russian rocket programs became enveloped in secrecy. The next reliable information was received by the West when the Nazi V-1's (and later the V-2's) began to bombard London. This effort was not small. Dr. Walter R. Dornberger, who was in charge of the V-2 program and retained meticulous records of the activity, disclosed after the war that 5085 V-2's were build and 3578 launched.[1] After the end of the European phase of World War II, many German rocketry experts were captured by the Russians, forcibly removed to Soviet territory along with the tools and equipment of their trade, and their lore and experience added to that of the Soviets.

The United States had used small solid-propellant rockets in the Pacific phase of the war, with ship-launched rockets being employed as "softening-up" devices prior to Marine landings on Japanese-held islands, and hand-held Bazookas being used in the attack of enemy strongpoints. No heavy boosters or liquid-motor rockets had been developed, however, and the field of use of these devices was felt to be small.

Postwar experimentation at the White Sands Proving Ground in New Mexico with a captured German V-2 brought the United States to the realization that this liquid-motor device, capable of a velocity of 3600 miles per hour and a range of 100 miles, was worth developing. The Air Force established the Rand (research and development) Project under the aegis of Douglas Aircraft Company in early 1946, and the first study produced by this group described a satellite vehicle using liquid fuel and multistage rockets. Dr. Theodore von Karman, one of the organizers of the Rand Project, subsequently surveyed the state of the art in Europe and came to the conclusion that the best method of increasing the range of the V-2 was to provide a set of wings for the missile. The United States elected to follow this course, which led to consideration of pilotless bombers flying at relatively low altitudes, and development of air-breathing missiles rather than pure rockets, which were self-contained and could operate outside the atmosphere.

The success of the Germans in developing the V-missiles and the later appearance of the atomic bomb led observers to believe that a quick "marriage" of the two would follow and inaugurate an era of "pushbutton warfare." Such estimates failed to evaluate properly the complexities attendant on the development of each device and the relatively primitive state of each.[2] Lacking were such factors as reliable guidance systems, competent propulsion systems, shock-resistant warheads, and the high-quality, or "clean-room," type of manufacturing facilities yet to be developed. However, early military characteristics for an air-to-ground missile had been proposed by the Army Air Force October 19, 1945, envisioning a warhead 60 inches in diameter, 130 inches long, and 11,000 pounds in weight (in obvious reference to the Fat Man bomb), although missiles capable of carrying a warhead of this size and weight would not be available for several years.

In March 1946 the Army Air Force directed the Air Materiel Command to develop an experimental missile, and this project was given a code name of MASTIFF.[3] At the time, little information regarding MASTIFF was made available to those working on the atomic bomb, but in one of his last actions, December 12, 1946, as head of the Manhattan Engineer District and prior to AEC assumption of control, Brig. Gen. Leslie R. Groves informed the Los Alamos Scientific Laboratory concerning the project, and stated that it envisaged installation of an atomic warhead in an air-to-ground guided missile.

This information was referred to the Z Division on January 10, 1947, with a request that preliminary analysis be made, but that any sizable amount of development work be deferred until later in the year when the work load was expected to taper off.[4] Subsequently, little was done on the project in either AEC or military circles beyond a general study that contemplated use of a plane-launched drone which would glide 300 miles to a target at a speed of 300 miles per hour. However, a drone with this speed was felt to be highly vulnerable to antiaircraft fire, and the existing scarcity of nuclear material, together with the inaccuracy of drone control systems, caused apprehension that an atomic weapon might be used to bomb some unoccupied field. In mid-1947, missile development for the MASTIFF project was assigned to Bell Aircraft Company, and was rescheduled as a long-range project to be preceded by SHRIKE, a 100-mile-range supersonic missile on which Bell had been intermittently engaged since 1945.

Subsequently, budget cuts in the 1946-1949 period reduced military participation in missile work. A 3-year period of recuperation, starting in 1950 and caused by the Korean War, partially restored financial support, but another retrenchment was made in 1953. It was not until 1956 that the missile program was consistently funded. Due to this early uncertainty, the Military gave preference to those devices which promised to reach production with the least expenditure of time and money. This generally relegated long-range missiles (which were those best suited to carrying atomic warheads) to low-priority status during the period.

The Division of Military Application notified the Military Liaison Committee, April 29, 1949, that some guided missiles being developed might reach a stage in the not too distant future where the desirability of employing them in conjunction with an atomic warhead should be considered.

This led to the establishment, June 21, 1949, of an Ad Hoc Committee, to consider the general problems of developing atomic warheads for guided missiles, and which reported to the Secretary for Defense. This Committee consisted of Lt. Gen. J. E. Hull, Director of the Air Force Weapons System Evaluation Group; Dr. F. L. Hovde, President of Purdue University; and Dr. N. E. Bradbury, Director of the Los Alamos Scientific Laboratory. This committee was to assess the possibilities for developing, within the next 5 to 10 years, guided missiles that might carry atomic warheads, and analyze the possible application of existing atomic weapons technology to the development of such warheads.[5]

The Ad Hoc Committee subsequently reported that Service requirements for a guided missile with an atomic warhead could be met within a reasonable time. It was concluded that four missiles could be adapted, with reasonable technical effort, to carry atomic warheads. These were the HERMES A-3 of the Army, a surface-to-surface rocket with a maximum range of about 100 miles; the REGULUS, a Navy surface-to-surface, jet-powered missile with approximately 500 mile range; the Air Force RASCAL, on air-to-surface missile of about 100-mile range; and the Air Force SNARK, a long-range, surface-to-surface, pilotless aircraft.[6]

There was general agreement that the principal obligation for marriage of warhead to missile would lie with the Sandia design group. Initial study showed that the major tasks would be those of providing arming and fuzing systems, and modifying components to withstand accelerations, temperatures, and vibrations existent in the guided-missile environment. A nuclear safing system would be required in at least some installations. The Joint Chiefs of Staff subsequently issued a list of priorities defining the over-all task, with the highest priority assigned to air-to-surface missiles, followed by short range surface-to-surface missiles, and long-range surface-to-surface missiles.

The Research and Development Board, which had been established in mid-1946 as a postwar replacement for the Office of Scientific Research and Development, notified the Military Liaison Committee, January 27, 1950, that the report of the Ad Hoc Committee had been accepted by the Secretary of Defense and the Joint Chiefs of Staff. The Board endorsed the selection of the four missiles for atomic warhead consideration, and added the Navy's CORPORAL, a surface-to-surface supersonic rocket which had a range of 70 miles. Several warheads were to be considered; the Mk 4 specifically for the SNARK, the Mk 5 for the REGULUS, and the Mk 8 for the HERMES.

A symposium was held at Sandia March 7-8, 1950, to provide mutual interchange of information between guided-missile contractors and warhead designers. The attendees at this meeting concluded that no insurmountable environmental or space problems were apparent, and that four atomic warhead designs were of immediate interest--the Mk 4, the TX-5, and the air-burst and penetrating versions of the TX-8.[7]

On October 1, 1950, Project E, Department 1270, was established at Sandia Corporation under the jurisdiction of the Director of Engineering. The task of this Department was to study the problems of integrating atomic warheads with guided missiles. A year later, this organization evolved into Engineering II, the guided-missile Directorate.

The Division of Military Application agreed, October 10, 1950, that the AEC would accept budgetary responsibility for all guided-missile warhead fuzing with coordination of each fuze development program being subject to recommendations of the Sandia Weapons Development Board, and that requirements for an air-burst gun-type warhead were deleted.[10]

A Guided Missiles Committee of the Sandia Weapons Development Board was appointed and initially met October 16, 1950. The committee discussed accelerations, vibrations, and general environmental conditions which would be experienced by guided missiles, and concluded that these could be withstood by atomic warheads. The Committee proposed that a separate Ad Hoc Working Group be established for each missile-warhead marriage program, with the Group proposing technical solutions to problems encountered in the programs.[11] The Board approved this suggestion, and these Ad Hoc Groups became a standard and important part of the missile program.[12]

The Committee also felt that specific fuzing systems for guided missiles would have to be developed, but that it should be initially possible to modify bomb fuzing systems. [redacted] It would be necessary to spell out carefully the relative priorities of the various programs, and the Committee felt that the current list of missiles should be considerably reduced in number. This list had been constantly changing, with the CORPORAL and SNARK being temporarily deleted, and additional versions of the HERMES, the RIGEL, NAVAHO, and TRITON being added.[13]

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The Military Liaison Committee added the Mk 7 Warhead to the missile application program November 3, 1950. It was agreed that an air-burst Mk 8 should be deleted, but that a penetrating Mk 8 Warhead should be retained, even though it was felt that a major development program would be required to provide sufficient resistance to shock and impact.[14]

The Guided Missiles Committee made a formal report to the Sandia Weapons Development Board November 27, 1950. At this time there were 10 different missiles being considered for marriage with three different warheads. Additionally, the suggestion had been made that alternate warehads be specified for some of the missiles, in the event the primary choice did not work out successfully.[15]

Nuclear safety was important, as some missiles would be launched from ground bases and it was felt that nuclear insertion should take place only after the missile had crossed over into enemy territory. Another safety problem was raised by the possibility of accidental crash of atomic warheads in friendly territory. It was felt that this impact might tear the capsule loose, propel it into the pit, and cause a full-scale detonation.

One solution was a fast-acting contact fuze which would tear the warhead apart before the high explosive could detonate, but an adequate switch was not available. The use of a capsule insertion device, offset from the loading axis in the safe position, was studied, but this design would have required more space than was available in some missiles and would have required different insertion mechanisms for bombs and warheads. A barrier, such as an iris or plate, was proposed, but it was felt that the capsule, due to its weight, might force its way through. After extensive discussion, it was decided that the added complications of this safety device would seriously decrease the operational reliability of the warhead, and it was decided to forego such safing.

Fuze design also required much study. It was originally hoped that a simple barometric fuze could be used, but the problem was complicated by the fact that two quite different types of missile flight profiles were involved, that of ballistic (where the missile was launched upward and then fell into a target) and that of release from a carrier downward onto a target.

The Division of Military Application notified the Military Liaison Committee, January 19, 1951, that increasing requirements for various combinations of missiles and warheads had reached the point where standardization of warhead design was becoming difficult, if not impossible, to achieve. It was felt that the design of the Mk 5 and Mk 7 Warheads had progressed to the point where these warheads could be proposed for marriage with missiles and eliminate any need for alternate warheads.[16]

A nomenclature system having the prefix "XW" to identify warheads under design, similar to the "TX" identification for bombs, was authorized in mid-January 1951. This prefix was followed by the warhead identification (Mark number) and was coupled with the missile designator for complete missile-warhead nomenclature. The "X" stood for experimental, and the "W" for warhead. A typical example was: XW-5/REGULUS.[17]

Detailed design was meanwhile proceeding on the arming system. It was felt that automatic arming should be provided, which would take place only after the missile had crossed into enemy territory, and it had been proposed that the missile guidance system be used to signal this fact. However, there was such a complexity of missiles, with different guidance systems, that this was found to be impracticable. It was possible, however, to provide a system that would sense the initial missile speed, the existence of high-enough thrust for long-enough time, the attainment of sufficient altitude, and the pursuance of the correct direction. All these factors could be gaged by gyroscopes, clocks and acceleration switches, and a system could be devised to permit nuclear insertion only when all these factors had been met or exceeded. Sandia provided such a system for all missile-warhead combinations, with the gyroscope, clock, or switch shorted out when a given missile had no need to measure that particular factor.[18]

Sandia presented a status report on its warhead-missile program February 23, 1951, when it was visited by Kaufman T. Keller, Chairman of the Board of the Chrysler Corporation, who had been appointed Director of the Guided Missiles Office by the Secretary of Defense. Keller noted that he had visited a good many places in his work as Missile Czar, but that he was "not going to worry about a place as obviously competent as this one." High praise indeed for Sandia work in this new field.[19]

Work began in earnest on warhead designs after AEC budgetary decisions were made May 31, 1951. It had become evident that much redesign would be required to strengthen the Mk 4 before it could be used as a warhead, and it was also evident that missiles capable of carrying such a heavy warhead were still some years in the future. Thus it was decided to suspend consideration of either the Mk 4 or Mk 6 weapon for current missile applications.

The question of fuzing responsibility was again raised. The first Ad Hoc Working Group to take action in this area, that for the XW-7/CORPORAL, recommended that Sandia provide an interim fuzing system, with Army Ordnance being responsible for the ultimate fuzing design. This proposal was approved by the Sandia Weapons Development Board June 27, 1951, and similar suggestions for the XW-5/REGULUS and XW-5/MATADOR were made and accepted in September and December 1951. These decisions were based on the fact that Sandia fuzes developed for bomb programs were the only systems capable of meeting time scales and adequately accomplishing the technical job.

Allocation of ultimate fuze design to the Army resulted in a request from that agency for AEC funds to develop an ultimate fuze for the XW-7/CORPORAL.[20] This request was referred to the Board, which decided in January 1952 to reduce the scope of the CORPORAL ultimate fuzing study to that of feasibility investigation.[21]

The fuze responsibility problem was again raised in the September 24, 1952, meeting of the XW-5/RASCAL Ad Hoc Working Group. Sandia and the Air Force presented opposing fuze-design proposals, and a clear-cut decision could not be reached. The problem was referred to the Guided Missiles Committee, which also could not reach unanimous decision, and it was in turn referred to the Special Weapons Development Board, where it was thoroughly discussed in a meeting November 12, 1952. The majority of the Board felt that Sandia should be assigned the fuzing task.

Meanwhile, the Air Force recommended to the Joint Chiefs of Staff that the Military be made responsible for all adaption-kit design (including that of the fuzing system) and that the interests of the AEC be confined to the design of the warhead proper. The Joint Chiefs of Staff endorsed this proposal and referred the decision through the Military Liaison Committee to the Division of Military Application. The DMA received this directive at almost the same time that it learned of the Board decision to assign the RASCAL fuzing responsibility to Sandia.

The Division of Military Application then reversed the decision of the Special Weapons Development Board, declaring, January 22, 1953, that basic responsibility for all guided-missile items of launcher, carrier, guidance, and fuzing would be assigned to the Military "... regardless of whether such parts are common to a standard rocket or missile or are required for use of the rocket or missile with a given atomic warhead."[22]

Subsequently, responsibilities of the Guided Missiles Committee were reviewed in the light of the above decision. It was decided to phase out this Committee and form new Joint Committees to replace the Ad Hoc Working Groups.[23] The major result of this change in policy was that the fuze-design responsibility was assigned to the missile contractor, who subsequently found that he could not produce fuzes with the proper capabilities within the time schedule, and who in turn subcontracted the fuze design back to Sandia.

Meanwhile, the Division of Military Application had issued a set of military characteristics September 11, 1951, covering an atomic warhead of the Mk 5 type for application to the MATADOR, REGULUS, HERMES, RASCAL, RIGEL, and

TRITON missiles. The warhead was not to exceed 44 inches in diameter, 77-1/2 inches in length, and 3000 pounds in weight.

[redacted]

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Nonradiating fuzes were felt to be highly desirable, setting of burst height was to be possible just prior to missile launching, and preflight checks were to be of a simple accept or reject type.

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A variety of interpretations had previously been given to definition of warhead and warhead installation, and were standardized by the Sandia Weapons Development Board December 11, 1951. The warhead was defined as the nuclear pit and capsule, high-explosive sphere, detonators, X-unit, firing switch, nuclear insertion mechanism, and all hardware and cabling pertaining to these items. The warhead installation included the warhead, arming and fuzing system, power supply, and installation hardware. The warhead installation thus might vary for different missiles, even though the same warhead was used.[25]

The XW-5 Warhead would contain a Mk 5 Bomb implosion system, a Mk 5 Firing Set with a fast-firing X-unit and switch for contact bursts, and a new linear nuclear insertion mechanism.[26] Mk 5 nuclear capsules would be used. This would produce a warhead 44 inches in diameter and 75-1/2 inches in length with a weight of 2550 pounds, excluding power supply, arming and fuzing, and mounting hardware.[27]

The Sandia Weapons Development Board ruled that the warhead installation should not be design released until six successful tests of the warhead in the missile had been made. Missile availability dates were still largely indefinite, but it was felt that at least 9 months would be required between design release and early production.

The Mk 5 Mod 0 Warhead was design released August 1953, and production was achieved July 1954. The warhead incorporated a linear nuclear insertion mechanism, but otherwise was identical with the Mk 5 Bomb less outer case. [redacted] A Mk 5 Mod 1 Warhead was proposed for use with the RASCAL missile, incorporating dual-motor nuclear insertion mechanism, but was canceled during design, April 16, 1956.[28]

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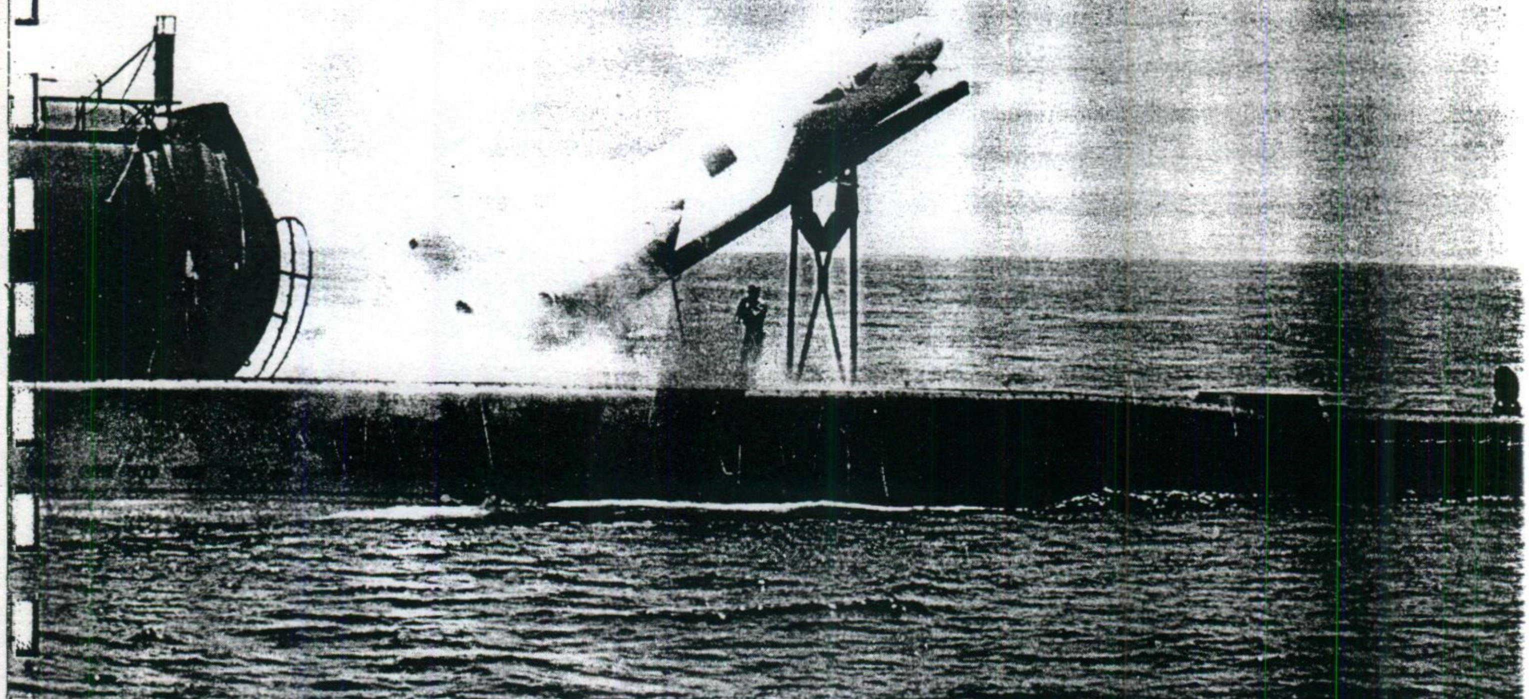

Figure 2. REGULUS Missile

CHAPTER II

MK 5/REGULUS WARHEAD

One of the earliest missile-warhead combinations to be considered was the Mk 5/REGULUS, approved for design by the Secretary of Defense January 1950. The REGULUS, being developed for the U. S. Navy by Chance-Vought Aircraft Company, was a subsonic, surface-to-surface, heavy bombardment missile capable of delivering a warhead to a range of 500 nautical miles.

The REGULUS was constructed in the shape of a streamlined fighter plane having a length of 34 feet, 40-degree swept-back wings with span of 21 feet, maximum diameter of about 5 feet, and weight of 14,000 pounds. The missile could be launched from submarine, ship or land base, using a short-rail launcher and two jettisonable solid-fuel jato rocket boosters. At launch, the missile climbed for about 6 minutes on a preset dead-reckoning course to an altitude of 35,000 feet. Automatic or command guidance was then instituted, and the missile traveled at Mach 0.9 to its terminal dive point, where automatic or radio-controlled Shoran guidance directed the missile to the target.

Since Shoran could provide location information, but not data concerning missile height above target, the weapon would be detonated by a radar installed in the missile. The XW-5 Warhead, including high-explosive sphere, nuclear insertion mechanism, and single-channel X-unit could be enclosed within the REGULUS shape.

A formal directive to place the missile-warhead in active design was released January 1951. This called for design completion January 1953, with the weapon to be tactically operational January 1954. The Navy felt that the missile could be provided with command guidance and be available as an interim weapon by mid-1952, and it was requested that this earlier date be met if possible. Both implosion and gun-type warheads were to be considered. The warhead was not to exceed a diameter of 45 inches, a length of 80 inches, or a weight of 3000 pounds.

Sandia noted that the mid-1952 date could only be achieved by an expedited development program, and it was not definite that either XW-5 or XW-8 Warheads would be available by early 1953. Submarine storage and use were not expected to be a problem, although special finishes and packaging would have to be developed to protect against humidity.[29]

An XW-5/REGULUS Ad Hoc Working Group was appointed and held its first meeting September 10, 1951. Several types of arming and fuzing systems were discussed, and it was agreed, in view of program urgency, to use existing components insofar as possible.[30] Thus, the arming mechanism would be a combination of timer and baroswitch, with the fuze having two Albert radars.

[redacted]

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Nonradiating fuzes were desirable but, in the event that a radar fuze was used, its minimum jamming resistance should approximate that of an improved Abee or Albert. External setting of the burst height just prior to missile launching was desired, as was a universal fuze that could be used with all missiles.[31]

It was decided that a simple timer-baroswitch device should be used in the initial arming design, with an electromechanical system developed for later use. A command arming system was also to be provided, to be employed in conjunction with the timer when operationally desirable. The Navy would be responsible for determination of the data on which the decision to arm or not to arm would be based, transmission of the arming signal from the ground, and reception of this signal in the missile. Sandia would be responsible for applying this arming signal to the warhead to cause nuclear insertion and would have complete responsibility for fuzing-system development. This approach was approved by the Sandia Weapons Development Board October 12, 1951.

Investigation was undertaken of both forward extending pressure probes and trailing devices. It was hoped to develop a simple barometric fuze, but tests showed that the pressure pickups did not give reproducible results, and that the missile would have to travel faster than Mach 1.0 to prevent premature fuze operation.[32] A decision was made to use a baro-armed radar fuze, a modification of the fuze design of the Mk 5 Bomb.[33]

In early 1952 the Mk 5/REGULUS was given a higher priority than its Mk 8 counterpart, since there was a limitation in the number of missiles available for test flights.[34] Work was started on a contact fuze for several missiles, and successful completion of this task made it possible to provide the XW-5/REGULUS with two fuzing options; radar air burst with contact-fuze backup, and surface burst by impact crystals.

The Navy had requested that a pure barometric fuze be developed, and this was discussed in the June 27, 1952, meeting of the Ad Hoc Working Group. Sandia reported that this design would require an additional 10 months, and that it was not at all certain that such fuze would have the required accuracy. The Group, after considerable discussion, decided to approve the radar fuze for use in the REGULUS and to continue development of a barometric fuze.

The RAM Program (for REGULUS Assault Missile) was initiated by a letter from the Military Liaison Committee to the Division of Military Application August 18, 1952. This was a project to provide the capability for launching the REGULUS missile from a surface ship, guiding the missile to target, and arming and detonating the warhead by command from carrier-based fighter aircraft.[35]

The program was given a high priority in mid-February 1953, and a small number of Mk 5 Bombs were placed in standby storage April 1953, together with the hardware to convert these bombs to RAM installation, which had been renamed the REGULUS Interim Capability Program. These units were subsequently retired in mid-1954, as normal XW-5/REGULUS components became available.[36]

The launching action closed two pullout switches which applied power to the timer motors. At the end of 6 minutes' safe-separation time, the timer made power available. If the command arming signal bypass switch was closed, the nuclear capsule was now inserted; otherwise, receipt of the command nuclear-arm signal resulted in this operation. When the missile "dump" signal was received, voltage was made available to relays controlled by an arming baroswitch. In addition, these arming relays connected the radar arm circuits to the fuze baroswitch.

When the missile descended to a pressure altitude of about 20,000 feet, the arming baroswitch closed, starting the inverters and charging the X-unit. At an altitude 700 feet higher than the desired height of burst, the fuze baroswitch closed and armed the radars, which began transmitting and receiving. If both radars were operating properly, the X-unit was triggered and caused detonation when the second of the two radars ranged. If one radar failed to range at its preset altitude, detonation occurred 300 feet lower, when the fourth element in the fuze baroswitch closed. This element effectively switched the radar firing lines from a series to a parallel connection. If both radars failed to operate, an impact-fuze system triggered the X-unit.

For the RAM mission, special plugs were installed which allowed the X-unit to be charged when a command electrical arm signal was received from the control aircraft. Transmission of a second command caused the nuclear insertion mechanism to operate, and subsequent issuance of the command-fire signal detonated the warhead. The impact fuze provided a backup.

Meanwhile work had been proceeding on a barometric fuze design. Some progress was made and, in the Ad Hoc Working Group meeting October 7, 1953, it was decided that the remaining REGULUS flight-test missiles would be used to prove out this system, which had been given the designation XW-5/RG-X1. Authorization for this modification was issued subsequently by the AEC and design release scheduled for June 1954.

Meanwhile, design and test work was proceeding on the XW-5/REGULUS. In the early stages of the project, it had been planned to use a remotely adjustable variable timer in conjunction with a command signal to prevent nuclear insertion from occurring while the missile was flying over friendly territory. Subsequently, this timer was deleted from the MATADOR installation (it had been initially planned for both missiles), and still later technical difficulties were encountered. Additionally, it was determined that the apparent safety provided by a variable timer was minor, since this timer had no direction or velocity sensing and would protect only the immediate vicinity of the launching platform. The fixed timer would have an interval of 6 minutes, and could be started at time of launch or at time of receipt of a radio command signal.

Flight tests of the Mk 5/REGULUS started October 28, 1952. The initial flight, and another one December 4, 1952, were successful from the standpoint of the warhead installation. The third flight, January 16, 1953, experienced power failure at time of dump, and all telemetry records were lost. The fourth flight, February 12, 1953, lasted for 16 minutes before the missile was destroyed. However, some information was obtained, and it was decided that the warhead installation could be design-released after a total of seven flights, or about mid-May 1953.

The Navy had been studying possible use of the Mk 5/REGULUS as a surface-to-air defense against aircraft formations, and requested Sandia to study the technical feasibility of warhead operation at altitudes of 40,000 feet. There were felt to be two problem areas; the ability of the X-unit to attain proper voltage without arcing over, and proper operation of the detonators under low-pressure conditions. Subsequent investigation resulted in a decision that the missile-warhead would operate properly, but at slightly reduced reliability.[37]

Complete design release of the Mk 5/REGULUS was effected September 1953, and production was achieved April 1954.

A new high-speed missile, the REGULUS II, was being developed. This would travel at twice the speed of the original REGULUS, or about Mach 2.0, and this increased velocity would more than double the ability of the missile to penetrate enemy defenses without being shot down. Test vehicles of the new design would be available by the fall of 1955, and a feasibility study was authorized by the Secretary of Defense December 1953.[38] The REGULUS II program was promoted to full-scale development stage in April 1955.[39]

Tests of the pressure-sensing system for the XW-5/RG-X1 showed that [redacted] This, however, required additional missile flights, and the design release date was postponed to January 1955.

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On August 19, 1954, the Military Liaison Committee proposed that responsibility for REGULUS adaption kits be transferred to the Navy. A meeting was held October 28, 1954, at which it was decided that this transfer would be made July 1, 1955.[40]

A production-model REGULUS, carrying a Mk 5 Warhead, was launched from the cruiser Los Angeles February 15, 1955, with the missile flight being controlled by an accompanying aircraft. Inflight insertion and command arming were accomplished satisfactorily, although the flight came to an abrupt termination when the warhead was accidentally detonated just short of the target. However, missile and warhead performance were satisfactory throughout the 23-minute flight, which covered 173 miles.[41]

Evaluation flights from submarines were largely successful. Impact tests indicated that the contact crystals generated sufficient voltage to detonate the warhead, and that this detonation occurred prior to warhead deformation. Impacts produced by travel through rain or hail, however, would not cause premature detonation. Thus, the system was given general release.

It had been suggested that the design with the barometric fuze be identified as a Mod change upon entry into stockpile. Action on this suggestion, however, was tabled pending assumption of design control by the Navy. Subsequently, it was decided that the Mk 5 Warhead would be replaced by the Mk 27, and all Sandia activity was suspended on the Mk 5/REGULUS Warhead Installation March 1, 1956.[42]

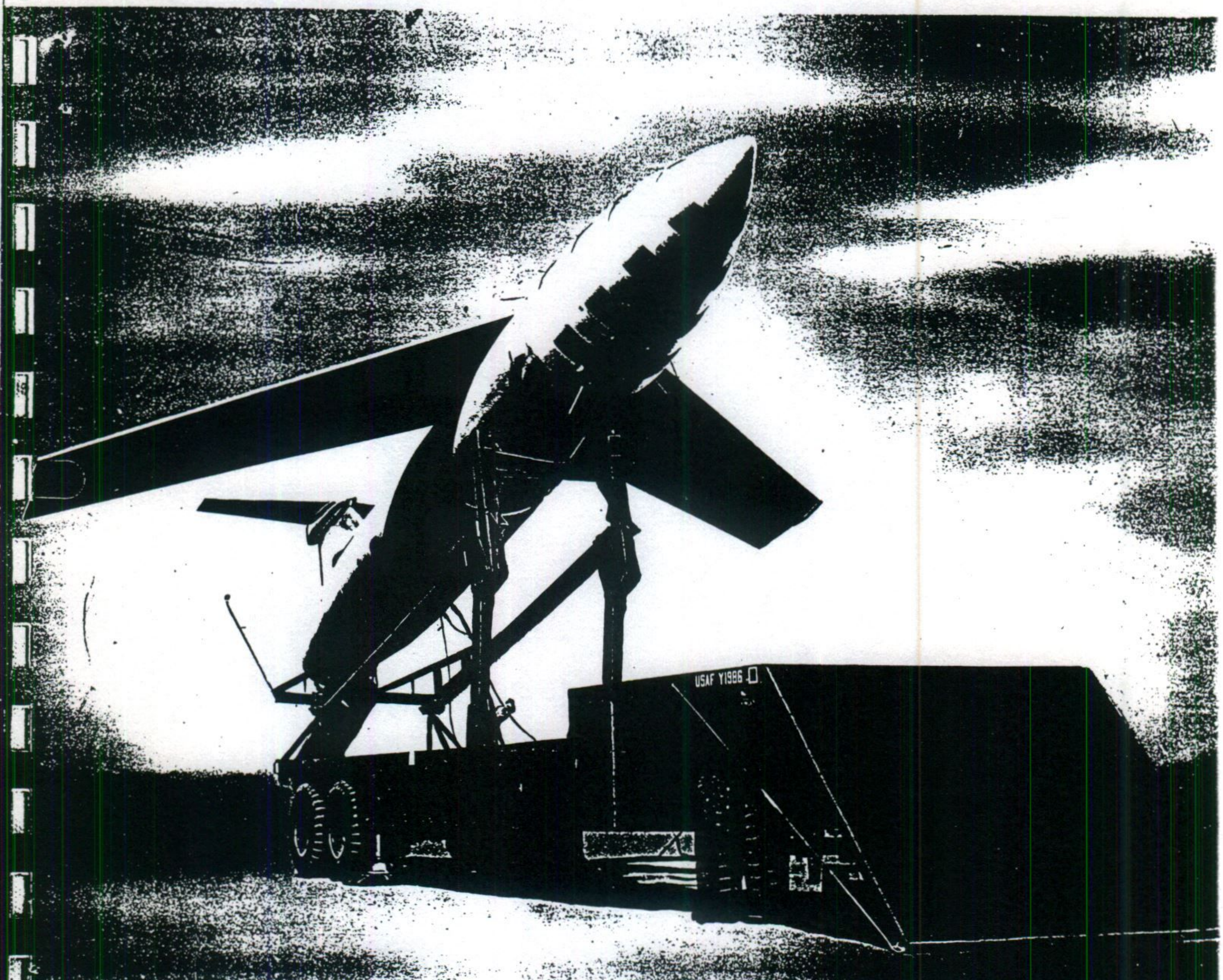

Figure 3. MATADOR Missile

CHAPTER III

MK 5/MATADOR WARHEAD

The MATADOR was a surface-to-surface, turbojet-powered, transonic missile with a range of about 600 nautical miles. The missile was constructed in the shape of a streamlined fighter plane with an over-all length of 39 feet, maximum diameter of slightly over 4 feet, and swept-back wings. It was launched from a zero-length launcher by a single, solid-propellant rocket, which accelerated the missile until the turbojet engine could attain enough thrust to sustain flight. This rocket booster was pneumatically ejected at time of burnout.

At launch, the missile climbed to an altitude of 40,000 feet, then followed a level trajectory to a "dump point" where it pushed over and dove into the target. Two guidance systems were proposed for use, Shanicle and Marc. Shanicle used four ground stations, which generated guidance beams. The missile received these signals and converted them into azimuth and range guidance. Marc used two trailers that tracked the missile and sent command signals. When the "dive point" was reached with either system, the missile followed a programmed terminal trajectory to the target. MATADOR was designed and built by the Glenn L. Martin Company for the Air Force.

The missile was initially considered for marriage with an XW-5 atomic warhead in early 1950.[43] The MATADOR project was accelerated in late 1950, due to the situation in Korea, and on December 18, 1950, the Joint Chiefs of Staff recommended to the Secretary of Defense that a number of missile projects be approved, among them the MATADOR.[44]

Much of 1951 was taken up with consideration of the solution of general problems relating to the development of atomic warheads for guided missiles, and it was not until October 3, 1951, that an XW-5/MATADOR Ad Hoc Working Group was named by the Guided Missiles Committee and held its first meeting. The Group proposed that both radiating and nonradiating fuzes be considered, but that--due to program urgency--the TX-5 bomb radar fuze be initially used. Several methods for warhead arming were proposed. One approach would use a clock timer in conjunction with the missile's gyro compass, and another design would incorporate command arming, using the missile's command guidance system. The first of these was felt to be the more reliable.

These recommendations were considered in the December 11, 1951, meeting of the Sandia Weapons Development Board. The Air Force would be responsible for determination of the data upon which the decision to arm or not to arm would be based, and for supplying a suitable signal to the warhead; and Sandia would be responsible for applying this signal to cause arming.[45]

The Division of Military Application wrote to the Military Liaison Committee February 4, 1952. Design release of the Mk 5/MATADOR warhead installation could not be made before February 1953, to allow sufficient time for six sytems flight tests, and production would require another year. The Department of Defense, however, had authorized substantial production of the missile for early 1952, and it thus appeared as though the nuclear warheads would lag the missile by about a year.[46] A request was made that the Mk 5/MATADOR program be expedited, but there appeared to be no way in which this schedule could be shortened.

Detailed consideration of the design in early 1952 resulted in a system that would use a timer which furnished an arming signal after the missile had crossed over into enemy territory. The guidance system would put the missile into a terminal dive if it deviated from its course. If the arming timer did not operate, no nuclear detonation would take place.

A trailing probe was tested to signal burst height by barometric means. However, this device had a number of disadvantages, including problems of storage and release after missile launch, time lag of operation, the fact that only one probe could be installed in the space available, and assembly problems. Nose probes were also studied, but these would require redesign or elimination of radars. A static pressure orifice on the warhead case appeared most promising.

In the midst of this design effort, Field Command stated that a nonradiating fuze was mandatory, that this system should use nose probes for pressure sensing, and that the design-release date must be accelerated.[47] In the ensuing meeting of the Ad Hoc Working Group, May 7, 1952, Sandia stated reluctance to replace the radar fuze with a baro design, in view of the many uncertainties and inaccuracies of the latter system. It was also pointed out that time scales would probably be lengthened by such a design change, rather than being shortened. After considerable discussion, the majority of the Group decided to continue effort on the radar fuze as the Mod 0 of the missile-warhead combination.[48]

On September 25, 1952, the Division of Military Application requested that the fuzing system of several missile-warheads, including the Mk 5/MATADOR, be modified to incorporate a contact fuze and provide means for controlling the armed or safed condition of the warhead during ground handling. This design change was made by Sandia and a report made to the November 13, 1952, meeting of the Group that [redacted] would be installed in the nose of the missile.[49] At this same meeting, a proposal was made and accepted that the Air Force be responsible for the design of an ultimate fuze, which would be a barometric type.[50] DOD b(3)

By early December 1952, warhead design work was essentially completed. The warhead would be installed in an ogival-shaped shell that formed the first 10 feet of the missile. Both a fiberglass and an aluminum nose were supplied, the latter to be used in the event its added strength was needed to support a nose probe. The sphere case of the Mk 5 Bomb would be used essentially unchanged, although one detonator cable was rerouted to avoid interference with the missile structure. The cartridge mounting structure had been reduced in weight, and a linear nuclear insertion mechanism installed. This mechanism could be operated either by command signal or arming timer.

A heading-error device built into the missile would cause it to enter a terminal dive, should the missile flight path stray more than certain specified limits from a preset course. An acceleration switch would operate 1 second after missile launch and close a safety switch. After the arming signal was received, a "dump" signal from the missile guidance system would start the fuzing sequence and initiate the terminal dive to the target. When the missile reached a point in the dive where external pressure was equal to one-half sea-level atmosphere, the X-arm baro would close, starting two inverters and charging the firing set. At a preset lower altitude, the fuzing baro would close, placing the two radars in operating condition. These two radars would initially be connected in series, and both would have to "range" (or operate) to detonate the bomb. Slightly below the desired burst altitude, these radars would be reconnected in parallel, so that operation of either radar would detonate the bomb. The impact fuze was not yet available, but was under development, and it was hoped to incorporate it in the Mod 0.

Meanwhile, missile production difficulties were being encountered. Early missile flight tests were also unsuccessful, with the arm signal failing to operate on the first flight; the missile breaking up in the terminal dive in the second; and the missile being destroyed in the third, when it became impossible to correct a severe deviation from the planned flight path. The design-release date was postponed to June 1953.

Three flights were made during March 1953, but all were unsatisfactory from the warhead standpoint, primarily due to missile failure. The AEC stated that it appeared undesirable to continue to divert Mk 5 high-explosive components from current production for use in MATADOR flights until the missile problems were solved and, as a result, further missile flights were postponed.[51]

After missile modifications were made, successful flights were made in August 1953, and warhead installation flights were resumed September 1953.[52] A MATADOR missile with a Mk 5 Warhead was launched from the Air Force Missile Test Center in Florida November 2, 1953. It accepted no commands after takeoff, and was eventually destroyed by removing all carrier guidance and allowing the missile to dive out of control. Reports of a crash in the Bahamas led to recovery of parts of the missile, but the warhead components were never located.[53]

In spite of the lack of flight-test verification, an interim release of the Mk 5/MATADOR warhead installation was made January 1954, and Report SC2982(TR), Interim Design Status Report of the XW-5/B-61A MATADOR, was approved by the Special Weapons Development Board. Additional missile difficulties then developed, and it appeared as though the final release could not be made for several months.[54]

On February 24, 1954, the Air Force Special Weapons Center requested Sandia to provide a barometric fuze for the Mk 5/MATADOR.[55] However, by this time the Military had assumed responsibility for design of new fuzing systems, and this problem was referred to the Air Force, with Sandia services as subcontractor being offered.[56]

Operation BLACK SWAN was established in the spring of 1954. This was a MATADOR Interim Capability Program under which bomb-to-warhead conversion components were supplied on an expedited basis, and associated with five Mk 5 Bombs for use in the event of national emergency.[57] These items were retained for possible use until late 1954.

Report SC3344(TR), Description and Status Report at Design Release of the XW-5/B-61A Atomic Warhead Installation, was presented to the June 30, 1954, meeting of the Special Weapons Development Board.[58] This report was accepted, after some revisions were made to the premature figures, and transmitted to the Division of Military Application. The Final Evaluation of the Mk 5/TM-61A

Atomic Warhead Installation, SC3560(TR), was also reviewed by the Board, July 13, 1955. [redacted] The warhead, although not being truly a universal design, incorporated many components from other weapons.[59]

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Some small effort was made to incorporate an XW-5-X1 Warhead containing the barometric fuze being developed by the Air Force. However, these plans were eventually dropped, and all effort ceased on the Mk 5/MATADOR project in early 1956.[60]

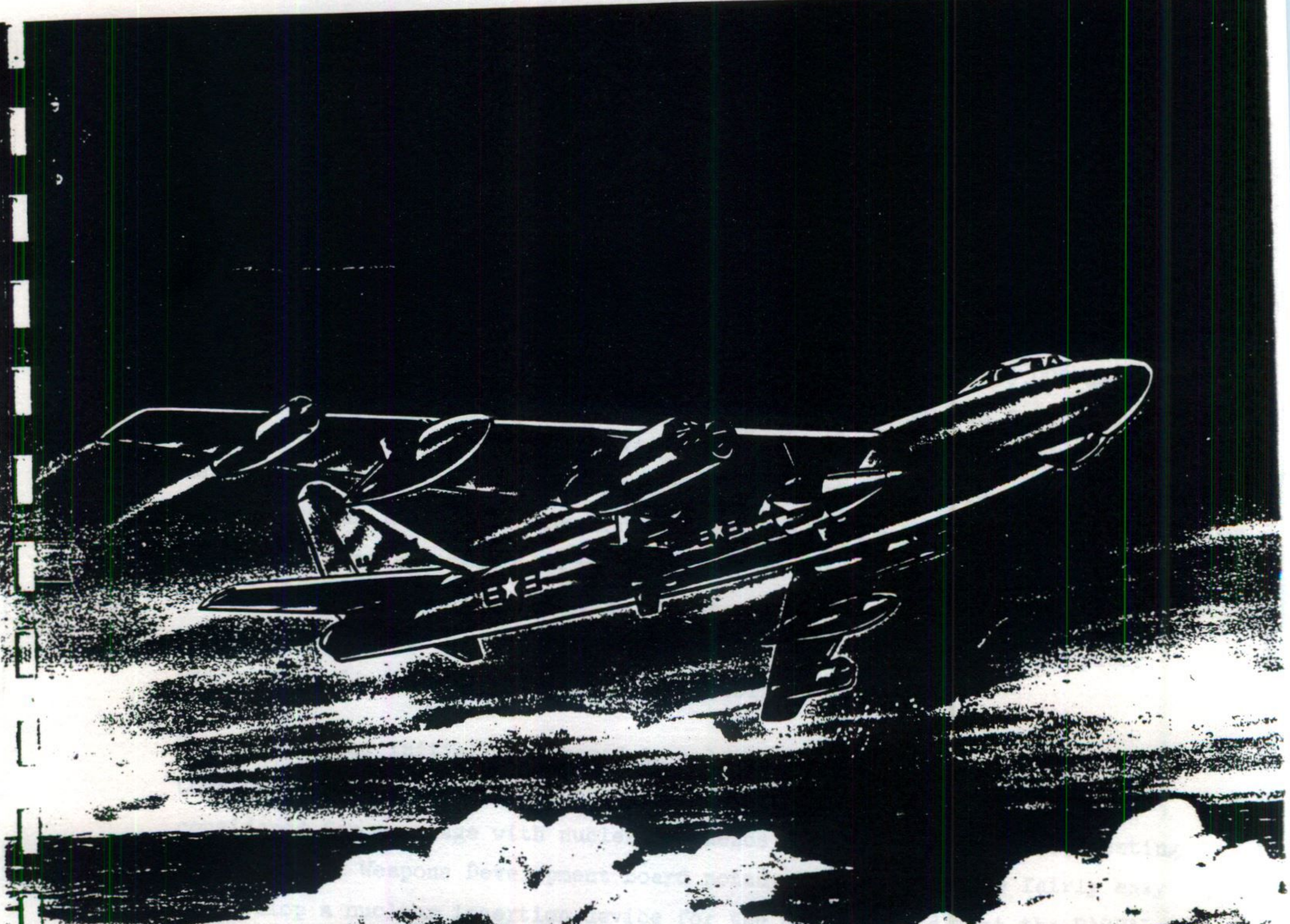

Figure 4. RASCAL Missile

A meeting of Sandia and Bell Aircraft personnel was held September 19, 1950, and initial plans for a missile-warhead formulated. The first glide missile drop was scheduled for April 1951, development launches for early 1952, and interim designs of the terminal guidance system for 1953. The test program would extend to mid-1954. It was suggested that a Mk 5 Bomb with nuclear insertion mechanism and existing fuze be repackaged to suit this missile-warhead combination.

An XW-5/RASCAL Ad Hoc Working Group was appointed and initially met November 7, 1951. The objectives of this Group were to consider problems of arming and fuzing, recommend assignment of tasks, and review proposed solutions.[62] At this time the problems of fuzing atomic warheads for guided missiles had been assigned jointly to the Military and the Atomic Energy Commission by the Department of Defense.

[redacted] of this objective was not to delay the operational date of the warhead installation. Nonradiating fuzes were desirable, although radiating fuzes would be acceptable if their resistance to jamming was equal to that of an improved Abee or Albert. The missile system would provide an arming signal. A universal fuze, applicable to several missiles, was desirable. Nuclear arming was to be possible at any time during the missile flight, and external means of safing the firing system should be designed.

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A study was made of possible means for retaining the nuclear capsule in the event the missile had to be jettisoned. Among the solutions proposed was a spherical clamshell and a removable door on the missile. However, there were many complexities and, as time passed, the problem of scarcity of nuclear material began to ease, and the requirement for capsule retention was dropped.

By early 1952 the design release of the warhead installation was scheduled for July 1954, early production a year later, and stockpiling by October 1955.[63] Shortly thereafter, it was felt that the program could be accelerated by about a year, due to the similarity of the design to the one already considered for the MATADOR missile.[64] The chief carriers of the missile-warhead would be the B-36 and B-47 Air Force bombers. The weapon would be carried in the rear bomb bay of the B-36, and on a pylon under the wing of the B-47.

It was proposed that Sandia design and provide the initial fuze, with a low-altitude fuze study being conducted by both Sandia and Bell Aircraft. Details of the Sandia fuzing system were discussed in the September 24, 1952, meeting of the Ad Hoc Working Group. Sandia advocated the use of a radar system, noting that jamming of these radars would be difficult and expensive. The Military desired a nonemanating fuze, and felt that the system should be of this type. Sandia agreed to develop both systems, with emphasis on a baro-fuze approach.[65]

The Military then proposed that the entire arming and fuzing task be assigned to the Air Force, since they felt that this system and the missile were closely interrelated.[66] This proposal was approved by a majority of the Group and referred, through the Guided Missiles Committee, to the Special Weapons Development Board.[67] The Board agreed that it would be desirable to develop a barometric fuze, since the shallow glide angle of the RASCAL compounded radar problems, but the majority of the Board felt that Sandia should develop the fuze.

The problem was then referred to the Division of Military Application, as noted in Chapter I, and final decision made to assign fuzing responsibility to the Air Force. The problem was turned over to the Bell Aircraft Company, which somewhat reluctantly issued subcontracts to various barometric-switch manufacturers for the development of suitable devices.

This fuze design program subsequently moved slowly, and it became evident that a satisfactory design would not be ready before the operational date of the missile. Sandia had meanwhile developed Fuze A, a baro-contact fuze, for the Mks 5, 6 and 13 Bombs and, on March 23, 1953, proposed to the Division of Military Application that this fuze be applied to the RASCAL missile.[68] The Air Force felt that Fuze A was more complex and expensive than necessary, but did authorize Bell Aircraft to procure most of the parts of Fuze A from Sandia and assemble these into a fuze for the RASCAL.

The low-voltage power supply for the arming and fuzing system was a matter of concern. Missile electrical power was furnished by turbogenerators, but these were operative only when the rocket engine was running. Sandia proposed installation of a battery to supply warhead power during the last part of the missile flight.

Meanwhile, the XW-5-X1 Warhead was being developed. It was suggested that this design be used, since it was fitted with dual nuclear insertion motors, which would be better adapted for operation under the high-acceleration environment of the RASCAL.

Missile difficulties now emerged, and the flight schedule was delayed by successive postponements. The first flight test was held May 5, 1955, but was prematurely terminated.[69] The next three launches produced successful tests of the warhead installation, but missile malfunctions still existed and, August 25, 1955, the Air Force Special Weapons Center notified Sandia that the RASCAL Operational Squadron had been canceled, and that plans were being made to provide a Class D thermonuclear-warhead capability for the missile.[70]

On November 15, 1955, the Air Force Special Weapons Center, supported by Sandia, recommended that the Mk 5 Warhead program for the RASCAL be terminated in favor of the Mk 27.[71] The Division of Military Application replied that the Air Force still desired a RASCAL capability with the XW-5 Warhead, and that Mk 5 flight tests were now scheduled for the period January through September 1956, while missiles configured to carry the XW-27 would not be available until October 1956.[72]

However, further study and negotiation resulted in cancellation of the Mk 5/RASCAL program in March 1956. A quantity of components and hardware to convert Mk 5 Bombs to XW-5-X1/RASCAL warhead installations was retained for a temporary period for possible combat use.[73]

CHAPTER V

MISCELLANEOUS MISSILES

RIGEL

Field Command notified Sandia August 28, 1950, that the Navy was planning to incorporate a Mk 5 Warhead into the RIGEL guided missile.[74] Information regarding this missile was requested from its contractor, the Grumman Aircraft Engineering Corporation, during a missile conference held at Sandia Base September 27-28, 1950. The Navy requested that provisions be made for the RIGEL to carry either the Mk 5, Mk 7 or Mk 8 Warhead.

Field Command pointed out to Sandia, in a letter dated November 29, 1950, that design of the RIGEL contemplated boosted launch from a short-rail launcher. The booster rockets would accelerate the missile from rest to approximately Mach 1.7 in about 4 seconds, after which the boosters would be jettisoned and the ramjet engines would further accelerate the missile to a cruising speed of Mach 2. During the boost phase, the longitudinal acceleration would be as high as 17 g's, and it appeared possible that accelerations of 20 g's might be experienced for short periods of time.[75]

The Mk 5 Warhead could withstand accelerations of 8 to 10 g's, but reduction of RIGEL launch accelerations to this level would require a major program, involving several years of research into composition and burning rates of propellants. Since the prototype warhead for the RIGEL would not be needed until 1954, it was hoped that a rugged implosion-type warhead might be developed by that time, and a request was made that Sandia make preliminary study of a Mk 5 implosion design that could withstand longitudinal accelerations of 20 g's.

A set of detailed missile characteristics was furnished to Sandia April 25, 1951.[76] This described the RIGEL as a supersonic, submarine-to-surface, bombardment missile with a maximum diameter of 45 inches, a length of over 45 feet, and able to carry a warhead weight of 3000 pounds.

After launch, the missile would climb to a cruising altitude of 50,000 feet and fly to an "area of influence" of guidance stations, where mid-course guidance would be provided. This system was a modified Loran type, using two submerged submarines as control stations. The missile would interrogate the submarines and fly along a hyperbolic path established by these replies. The replies were timed so that the missile path would pass through a target release point. At this point the missile would automatically push over into either a programmed ballistic or homing path to the target. The first tactical missile firing was planned for November 1952, initial firing from a submarine in November 1954, and Fleet evaluation in December 1955.

Little subsequent work was done, however, and, September 30, 1953, the Division of Military Application notified Santa Fe Operations Office that the RIGEL program had been canceled and that requirements for an atomic warhead installation for this missile had been withdrawn.[77]

HERMES

The Sandia Weapons Development Board was notified March 13, 1951, that the Army was developing proximity fuzes for use with the HERMES missile carrying a conventional warhead. It was noted that the military characteristics for these fuzes were similar to those of atomic weapons, except for the higher reliability required in atomic weapons. Inasmuch as this increase in reliability could be achieved by using multiple fuzing, it was suggested that the Board make formal assignment of this project to the Army.[78]

On May 21, 1951, the Division of Military Application sent a teletype to Sandia, stating that the HERMES missile had been deleted from the marriage program, and that the Sandia program should be adjusted accordingly.[79] The

Military Liaison Committee notified the Division of Military Application on June 4, 1951, that the missile had been formally removed from the list of approved weapons projects, but that it had been added to the list of guided-missile test vehicles.[80]

Meetings were held in late 1951, to discuss the possibilities of reinstating the Mk 5 Warhead into the HERMES, so that a missile warhead-compartment design could be produced that would be compatible with Sandia's handling equipment. By May 27, 1952, schedules were being firmed up. Static tests would start April 1953, and flight tests July 1953. The missile operational date would be late 1954, with full production by early 1956. Operational suitability tests of the Mk 5 Warhead in the HERMES missile were planned for mid-1954.[81] General Electric Company, contractor for the HERMES missile, proposed that Sandia enter the project January 1954, by which date the third missile would be available for use.

Sandia was assigned design responsibility for the nose cone, which would have to be pressurized during flight to prevent electrical breakdown of the components. Some difficulty was anticipated with sealing problems, since the ring on which the nose cone was mounted did not lend itself readily to such designs. Sandia suggested, in a letter to Field Command June 9, 1952, that the nose cone be redesigned by the missile contractor, since it was closely associated with the missile airframe design.[82]

Sandia notified the Sandia Field Office of the AEC, June 11, 1952, that conferences with the missile contractor had determined that systems tests could start no earlier than October 1953. Design release would be accomplished by March 1954.[83]

Sandia wrote to Field Command September 25, 1952, stating that nose cones would be furnished for test flights of all HERMES missiles. These would contain inert warheads and Sandia-designed fuzes. It appeared that either a barometrically armed radar fuze or a pure barometric fuze would be used, but it was stated that design responsibility for the fuze had not been formally assigned.

On October 16, 1952, Field Command stated that, due to budget cuts, the HERMES program would be delayed about 6 months.[84] Thus, no current action would be taken on the formation of an Ad Hoc Working Group.[85]

Fiscal funds were still lacking by August 25, 1953.[86] On September 18, 1953, the Military Liaison Committee notified the Division of Military Application that the Army had terminated the development of the HERMES missile as an operational weapon, and that the requirement for an atomic warhead installation for this missile was accordingly withdrawn.[87]

F-101

On April 9, 1953, the Division of Military Application notified Santa Fe Operations Office that the Joint Chiefs of Staff had established a military requirement for development of a streamlined case to enable a supersonic fighter-type aircraft to externally carry the Mk 5 Bomb. Initial application was to be made to F-101 aircraft, and it was considered desirable that the Air Force proceed with the development of the case and the associated non-nuclear components.[88]

A study was made by Wright Air Development Center, after which the Air Force directed McDonnell Aircraft Corporation to develop an externally carried case, named Store 96. This Store was a symmetrical shape 394 inches long and with a maximum diameter of 44 inches. It had three tail fins, with the lower fin retractable to provide ground clearance for loading the weapon and for takeoffs and landings. Gross weight of the shape, including the Mk 5 Warhead and 849 gallons of fuel, was 9240 pounds. The fuel would be expended by the aircraft en route to the target, and, at release, with all fuel expended, the Store would weigh 3776 pounds. The weapon could be released from the carrying aircraft by low-altitude bombing release, M-1 bombing computing system, or by dive bombing, with optical sighting. An ejector mechanism would assist to separate the bomb from the airplane at release.

By fall 1953, the design had progressed to the point where initial test flights could be undertaken by mid-1954 and operational capability could be achieved by January 1956. Early flight tests would be made in B-47 bombers, with 15 drops being made to check out weapon stability and barometric sensing. A subsequent test series would check the fuzing and firing system, and separation under varying conditions.[89]

An XW-5/F-101 Joint Project Group was formed August 1953 to coordinate activities of the Armed Forces Special Weapons Project, the Air Force Special Weapons Center, and Sandia in the shape 96 project.[90] By the July 20, 1954, meeting of the Group, it had been decided to use a radar-timer-contact fuze, and to discard a baro-timer-contact design that had also been considered.[91]

On April 26, 1955, AEC notified Sandia that thermonuclear warheads should be considered for application to the Shape 96. Sandia would provide an appropriate arming and fuzing system.[92] Some thought was given to the application of a Mk 15 Warhead, but this proposal was deleted.[93] In March 1956 the Air Research and Development Command canceled the applications of both the Mk 5 and Mk 27 programs to the F-101, as flight tests had demonstrated fairing problems causing buffeting.[94] Attempts were made to solve these problems; but the program had been delayed to the point that other, and better, weapon combinations became available.[95]

Glossary of Mk 5 Warhead Terms

Air Force Special Weapons Center -- That element of the Air Force Systems Command having to do with compatibility testing of nuclear devices with aircraft. Located at Kirtland Air Force Base, Albuquerque, New Mexico.

Armed Forces Special Weapons Project -- An interdepartment agency formed to handle military functions related to atomic weapons.

Barometric Fuze -- Fuze incorporating a baroswitch. A pressure device actuated by increasing air pressure as the warhead descends in its trajectory.

Capsule -- The nuclear ~~capsule~~ element of an atomic weapon which, when subjected to compression in the implosion process, becomes supercritical and produces a nuclear reaction.

Cartridge -- An assembly, generally containing fuzing and firing system elements, which can be inserted and removed from an atomic weapon in the manner of a cartridge being inserted or removed from the chamber of a rifle.

Contact Fuze -- A fuze that detonates the weapon by contact with the ground or the target.

Department of Defense -- The Armed Forces, i.e., the Army, Navy and Air Force.

Detonators -- Explosive devices which when initiated by the X-unit ignite the lens charges of the high explosive sphere, ~~Devices containing bridge wires which, when subjected to an electrical load, burn rapidly and act as a match to apply a flame to various points on the outer surface of the high-explosive sphere.~~

Division of Military Application -- An AEC office that functions as liaison between the Military and weapon designers and producers.

Dump -- The point in its trajectory at which a guided missile "dumps" or turns toward the target.

Fat Man Bomb -- The implosion device used during World War II in the attack on Nagasaki. So-called due to its bulging contour.

Field Command -- The local office of the Armed Forces Special Weapons Project, located on Sandia Base, Albuquerque, New Mexico.

Fuze -- A combination of the arming and firing devices of a weapon.

g -- Force equal to one unit gravity.

provided with appropriate lens charges to initiate the explosion

Implosion -- The effect created when a sphere of high explosive is detonated on its exterior surface. The force of the exploding wave is directed largely toward the center of the sphere.

Jato -- Named for Jet-Assisted Take-Off. A jet device initially designed to assist heavily loaded aircraft to take off from short runways. Used as a boosting device in missile launching.

A group composed of the Chiefs of Staff of the

Joint Chiefs of Staff -- ~~An~~ Army, Navy and Air Force ~~group~~ to determine policy and to develop joint strategic objectives of the Armed Forces.

Kiloton -- A means of measuring the yield of an atomic device by comparing its output with the effect of an explosion of TNT. A 1-kiloton yield is equivalent to the detonation effect of 1000 tons of high explosive.

Los Alamos Scientific Laboratory -- A nuclear design organization located at Los Alamos, New Mexico.

Mach -- A measure of speed. Mach 1.0 is the speed of sound, or 738 miles per hour at sea level.

Mark 27 -- A relatively small and light thermonuclear weapon, developed both as bomb and warhead.

Military Liaison Committee -- A Department of Defense Committee established by the Atomic Energy Act to advise and consult with the AEC on all matters relating to military applications of atomic energy.

Nautical Mile -- A naval measurement of length. One nautical mile is equivalent to 6076.1033 feet, or the length of 1 minute of arc (1/21,600) of a great circle of the earth.

Prototype -- An early weapon type, generally hand-produced before a production run.

Proximity Fuze -- A fuze that detonates the weapon as soon as it comes within a certain specified distance of the ground or target.

hollow metal shell which receives

Pit -- The ~~space~~ at the center of an implosion bomb. ~~The~~ the nuclear capsule is inserted into this space.

Radar -- Named for Radio Detecting and Ranging. Radars emit a pulse of high-frequency energy and measure the time lapse from that transmission to receipt of a reflected electrical "echo" from an object. This time measurement determines the distance of the object from the transmitting antenna of the radar.

<u>Sandia Weapons Development Board</u> -- A joint Sandia-Military board at Sandia Base to provide local guidance on weapons design.

<u>Santa Fe Operations Office</u> -- The local office of the Atomic Energy Commission (AEC) concerned with the operations of Sandia Corporation.

<u>Special Weapons Development Board</u> -- Change of name for the Sandia Weapons Development Board, effective May 14, 1952.

<u>Subsonic</u> -- Any speed below that of Mach 1.0, which is the speed of sound, or 738 miles per hour at sea level.

<u>Supersonic</u> -- Any speed exceeding that of Mach 1.0.

<u>Telemetry</u> -- The transmission of signals from a moving object.

<u>Thermonuclear</u> -- Two-stage reaction, with a fission device exploding and starting a fusion reaction in light elements.

<u>X-Unit</u> -- ~~A high voltage transformer.~~ A device used to provide high voltage to the weapon detonators.

<u>XW-8</u> -- A gun-type weapon, designed for target penetration.

<u>Z Division</u> -- A division of the Los Alamos Scientific Laboratory, elements of which moved to Sandia Base and became the nucleus of Sandia Laboratory.

References

1. Unc Ltr, Walter R. Dornberger to Redstone Arsenal, dtd 6/8/51. SC Archives, microfilm reel MF-SF-SC-134.

2. TSRD Report, A History of the Air Force Atomic Energy Program, 1943-1953; Vol. IV, The Development of Weapons, by Lee Bowen. Historical Division Files, Kirtland Air Force Base.

3. TSRD Report, The History of Air Force Participation in the Atomic Energy Program, 1943-1953; Vol. II, Foundation of an Atomic Air Force and Operation Sandstone, by A. D. Little. Historical Division Files, Kirtland Air Force Base.

4. SRD Ltr, Z Division to Supervisors, dtd 1/10/47, subject, Atomic Warhead in a Guided Missile. SC Archives, microfilm reel MF-SF-SC-3.

5. SRD Ltr, Division of Military Application to Sandia Laboratory, dtd 6/29/49. AEC Files, MRA-5, Vol. V, 1949-50.

6. SRD Ltr, Sandia Research to Engineering, dtd 8/26/49, subject, Proposed Conference on Guided Bomb. SC Archives, Internal microfilm reel 745.

7. SRD Ltr, Research and Development Board, Washington, D. C., to Military Liaison Committee, dtd 1/27/50, subject, Guided Missiles with Atomic Warheads. AEC Files, MRA-5, 4/49-6/50.

8. SRD Minutes, RS 3466/61222, Sandia Weapons Development Board to Distribution, dtd 6/21/50, subject, Minutes of 39th Meeting. SC Archives, Transfer No. 48217.

9. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 6/14/50, subject, Guided Missile Fuzing. SC Archives, microfilm reel MF-SF-SC-101.

10. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 10/10/50, subject, Guided Missiles with Atomic Warheads. SC Archives, microfilm reel MF-SF-SC-101.

11. SRD Minutes, RS 3466/67993, Guided Missile Committee to Sandia Weapons Development Board, dtd 10/16/50, subject, Minutes of 1st Meeting. Filed as Addendum No. 8 to the 46th meeting of the Board. SC Archives, Transfer No. 48217.

12. SRD Minutes, RS 3466/90268, Sandia Weapons Development Board to Distribution, dtd 10/18/50, subject, Minutes of the 45th Meeting. SC Archives, Transfer No. 48217.

13. SRD Ltr, Military Liaison Committee to Division of Military Application, dtd 7/6/50, subject, Guided Missiles with Atomic Warheads. SC Archives, microfilm reel MF-SF-SC-1459.

14. SRD Ltr, Military Liaison Committee to Division of Military Application, dtd 11/3/50, subject, Definition of Responsibility in the Marriage Program of Guided Missiles to Atomic Warheads. AEC Files, MRA-5, 7/50-6/51.

15. SRD Report, Committee on Guided Missiles to Sandia Weapons Development Board, dtd 11/27/50, subject, 1st Report. SC Archives, microfilm reel MF-SF-SC-134.

16. SRD Ltr, Division of Military Application to Military Liaison Committee, dtd 1/19/51, subject, Atomic Warheads for Guided Missiles. SC Archives, microfilm reel MF-SF-SC-134.

17. SRD Ltr, Santa Fe Operations Office to Los Alamos Scientific Laboratory and Sandia Corporation, dtd 1/19/51, subject, Implosion Type Weapon Program. SC Archives, microfilm reel MF-SF-SC-134.

18. SRD Report, RS 1270/36, Sandia Corporation to File, dtd 2/1/51, subject, Proposed Nuclear Arming System for Atomic Warheads Used with Guided Missiles. SC Archives, microfilm reel MF-SF-SC-113.

19. CRD Ltr, Sandia Corporation to Distribution, dtd 2/15/51. SC Archives, microfilm reel MF-SF-SC-134.

20. SRD TWX, Division of Military Application to Sandia Field Office, AEC, dtd 1/7/52. SC Archives, microfilm reel MF-SF-SC-103.

21. SRD Ltr, Sandia Corporation to Division of Military Applicaltion, dtd 3/4/52, subject, Evaluation of Arming and Fuzing Responsibilities for Atomic Warheads. SC Archives, microfilm reel MF-SF-SC-1459.

22. SRD Ltr, Santa Fe Operations Office to Los Alamos Scientific Laboratory and Sandia Corporation, dtd 2/9/53, subject, Missile and Rocket Responsibilities. AEC Files, MRA-5, 1/53-2/53.

23. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 7/30/53, subject, Missile and Rocket Responsibility. AEC Files, MRA-5, 7/53-8/53.

24. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 9/11/51, subject, Military Characteristics of the [redacted] Atomic Warhead for Guided Missiles. AEC Files, MRA-5, Vol. III, 7/51-1/52.

25. SRD Ltr, Los Alamos Scientific Laboratory and Sandia Corporation to Santa Fe Operations Office, dtd 12/21/51, subject, XW-5 Warhead and XW-5/(Missile) Warhead Installation Program. SC Archives, microfilm reel MF-SF-SC-134.

26. SRD Ltr, TX-N Steering Committee to Los Alamos Scientific Laboratory and Sandia Corporation, dtd 12/4/51, subject, XW-5 Warhead and Warhead Installation Development Program. SC Archives, microfilm reel MF-SF-SC-134.

27. SRD Report, TX-N Steering Committee to Distribution, dtd 12/4/51, subject, Tentative Characteristics of the XW-5 Warhead and XW-5/Missile Warhead Installations. SC Archives, microfilm reel MF-SF-SC-103.

28. CRD Ltr, Sandia Corporation to Distribution, dtd 5/16/56, subject, Cancellation of XW-5-X1 Warhead Development Program. SC Central Technical Files, XW 5-1, 5-2.

29. SRD Ltr, Sandia Corporation to Armed Forces Special Weapons Project, dtd 1/23/51, subject, Sandia Corporation Preliminary Comments on "Military Characteristics for Atomic Warheads for REGULUS (XSSM-N-8)." SC Archives, microfilm reel MF-SF-SC-138.

30. SRD Report, REGULUS/TX-5 Ad Hoc Working Group to Distribution, dtd 9/10/51, subject, Meeting Held August 16-17, 1951. SC Archives, microfilm reel MF-SF-SC-138.

31. SRD Minutes, REGULUS/TX-5 Ad Hoc Working Group to Distribution, dtd 9/18/51, subject, Minutes of 2nd Meeting. SC Central Technical Files, XW-5/REGULUS, 1-.

32. SRD Ltr, RS 3466/60759, Guided Missiles Committee to Special Weapons Development Board, 9/26/51, subject, Initial Recommendations on REGULUS/TX-5 Arming and Fuzing, Addendum D to the 55th Meeting of the Board. SC Archives, Transfer No. 48217.

33. SRD Ltr, Sandia Corporation to Armed Forces Special Weapons Project, dtd 9/26/51, subject, Nose Boom for REGULUS. SC Central Technical Files, XW-5/REGULUS, 1-.

34. SRD Ltr, Field Command to Sandia Corporation, dtd 1/18/52, subject, Relative Priorities for XW-5 and XW-8 Warheads for REGULUS Missiles. AEC Files, MRA-5, 1/52-11/52.

35. SRD Ltr, Military Liaison Committee to Division of Military Application, dtd 8/18/52, subject, Requirements in Connection with the REGULUS Assault Missile (Project RAM). SC Archives, microfilm reel, MF-SF-SC-138.

36. SRD Ltr, Santa Fe Operations Office to Sandia Corporation, dtd 6/2/54, subject, REGULUS Interim Capability. AEC Files, MRA-5, 5/54-6/54.

37. SRD Ltr, RS 1000/1415, Sandia Corporation to Field Command, dtd 10/6/53, subject, High Altitude Capabilities of the XW-5/REGULUS. AEC Files, MRA-5, REGULUS, Vol. IV.

38. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 12/10/53, subject, Supersonic REGULUS Warhead. AEC Files, MRA-5, 11/53-1/54.

39. SRD Ltr, Santa Fe Operations Office to Sandia Corporation, dtd 4/13/55, subject, Promotion of Projects to Stage 2 (Full Scale Development). AEC Files, MRA-5, 10/54-6/55.

40. SRD Ltr, Santa Fe Operations Office to Bureau of Ordnance, dtd 11/23/54, subject, Transfer of AEC Responsibilities for REGULUS Adaption Kits to the Department of the Navy. AEC Files, MRA-5, REGULUS, 7/54.

41. SRD Minutes, REGULUS I and REGULUS II Coordinating Committee to Distribution, dtd 3/16/55, subject, Minutes of the 3rd Meeting. AEC Files, MRA-5.

42. SRD Ltr, Chief of Naval Operations to Bureau of Aeronautics, dtd 3/15/56, subject, REGULUS XW-5 Warhead Fuzing Systems; Change of. AEC Files, MRA-5, REGULUS, 3/56.

43. SRD Report, Department 1270 to File, dtd 12/14/50, subject, Report of Trip to the Pentagon, Washington, D. C. SC Archives, microfilm reel MF-SF-SC-134.

44. SRD Ltr, RS 3466/67994, Armed Forces Special Weapons Project, Washington, D.C to Field Command, dtd 1/9/51, subject, Guided Missiles with Atomic Warheads, Addendum A to 48th Meeting, Sandia Weapons Development Board. SC Archives, Transfer No. 48217.

45. SRD Minutes, RS 3466/61070, Sandia Weapons Development Board to Distribution, dtd 12/11/51, subject, Minutes of the 58th Meeting. SC Archives, Transfer No. 48217.

46. SRD Ltr, Division of Military Application to Military Liaison Committee. dtd 2/4/52, subject, Military Characteristics for the [redacted] Diameter Atomic Warhead (and Warhead Installation) for Guided Missiles. SC Archives, microfilm reel MF-SF-SC-134.

47. SRD Ltr, Field Command to Sandia Corporation, dtd 4/22/52, subject, Interim Fuzing System for XW-5/MATADOR. AEC Files, MRA-5, MATADOR, Vol. I.

48. SRD Minutes, XW-5/MATADOR Ad Hoc Working Group to Distribution, dtd 5/7/52, subject, Minutes of the 6th Meeting. AEC Files, MRA-5.

49. SRD Minutes, XW-5/MATADOR Ad Hoc Working Group to Distribution, dtd 11/13/52, subject, Minutes of the 8th Meeting. AEC Files, MRA-5.

50. SRD Minutes, XW-5/MATADOR Ad Hoc Working Group to Distribution, dtd 12/6/52, subject, Minutes of Meeting. SC Central Technical Files, XW-5/MATADOR, 2-, 1951-8.

51. SRD TWX, Santa Fe Operations Office to Sandia Field Office, AEC, dtd 4/9/53. AEC Files, MRA-5, MATADOR, Vol. II.

52. SRD TWX, RS 1/522, Sandia Corporation to Division of Military Application, dtd 8/23/53. AEC Files, MRA-5, 7/53-8/53.

53. SRD Ltr, Sandia Field Office, AEC, to Division of Military Application, dtd 12/16/53, subject, MATADOR Missile Containing XW-5 Warhead. AEC Files, MRA-5, 11/53-1/54.

54. SRD Ltr, RS 1/565, Sandia Corporation to Division of Military Application, dtd 1/18/54, subject, Transmittal of Interim Design Status Report of the XW-5/B-61A MATADOR, SC2982(TR). AEC Files, MRA-5, 11/53-1/54.

55. SRD Ltr, Air Force Special Weapons Center to Sandia Corporation, dtd 2/24/54, subject, Design Improvements in the XW-5/B-61A Warhead Installation. AEC Files, MRA-5, 2/54-4/54.

56. SRD Ltr, Sandia Field Office, AEC, to Air Force Special Weapons Center, dtd 3/16/54, subject, Design Improvements in the XW-5/B-61A Warhead Installation. AEC Files, MRA-5, 2/54-4/54.

57. SRD Ltr, Field Command to Santa Fe Operations Office, dtd 3/17/54, subject, Early Emergency Capability XW-5/MATADOR. AEC Files, MRA-5, MATADOR, Vol. III.

58. SRD Minutes, RS 3466/80010, Special Weapons Development Board to Distribution, dtd 6/30/54, subject, Minutes of the 84th Meeting, Part I. SC Archives, Transfer No. 48217.

59. SRD Minutes, RS 3466/78375, Special Weapons Development Board to Distribution, dtd 7/13/55, subject, Minutes of the 94th Meeting, Part I. SC Archives, Transfer No. 48217.

60. SRD Ltr, Santa Fe Operations Office to Sandia Corporation, dtd 3/8/56, subject, Cancellation of XW-5-X1/TM-61C (MATADOR) Project. AEC Files, MRA-5, MATADOR, 7/55.

61. CRD Ltr, Sandia Corporation to Distribution, dtd 10/25/50, subject, Visit of Bell Aircraft Personnel Concerning the TX-5 Warhead for the RASCAL Missile. SC Archives, microfilm reel MF-SF-SC-135.

62. SRD Minutes, RASCAL/XW-5 Ad Hoc Working Group to Distribution, dtd 11/7/51, subject, Minutes of Meeting. SC Archives, microfilm reel MF-SF-SC-135.

63. SRD Ltr, RS 1000/958, Sandia Corporation to Sandia Field Office, AEC, dtd 5/24/52, subject, Estimated Complete Design Release Date for the XW-5/RASCAL Warhead Installation. AEC Files, MRA-5, 4/52-6/52.

64. SRD TWX, Division of Military Application to Sandia Corporation, dtd 9/9/52. AEC Files, MRA-5, RASCAL.

65. SRD Minutes, XW-5/RASCAL Ad Hoc Working Group to Distribution, dtd 9/24/52, subject, Minutes of 5th Meeting. AEC Files, MRA-5, RASCAL.

66. SRD Ltr, Santa Fe Operations Office to Sandia Field Office, AEC, and Sandia Corporation, dtd 1/19/53, subject, XW-5/RASCAL Fuzing Development. AEC Files, MRA-5, 1/53-2/53.

67. SRD Ltr, Division of Military Application to Santa Fe Operations Office dtd 1/22/53, subject, XW-5/RASCAL Fuzing. AEC Files, MRA-5, 1/53-2/53.

68. SRD Ltr, RS 1/457, Sandia Corporation to Division of Military Application, dtd 3/23/53, subject, Sandia Corporation Proposal for XW-5/RASCAL Fuzing System. AEC Files, MRA-5, RASCAL.

69. SRD Ltr, RS 1200/1502, Sandia Corporation to Field Command, dtd 7/8/55, subject, Rescheduling of the GAM-63 Application of the XW-5-X1 Warhead. AEC Files, MRA-5, RASCAL, 7/55.

70. SRD Ltr, Air Force Special Weapons Center to Sandia Corporation, dtd 8/25/55, subject, Reorientation of the GAM-63 Program. AEC Files, MRA-5, RASCAL, 7/55.

71. SRD Ltr, Air Force Special Weapons Center to Air Research and Development Command, dtd 11/15/55, subject, Cancellation of XW-5 Warhead Capability in the GAM-63. AEC Files, MRA-5, RASCAL, 7/55.

72. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 12/27/55, subject, Proposed Reorientation of the GAM-63 Program. AEC Files, MRA-5, RASCAL, 7/55.

73. CRD Ltr, RS 1200/1735, Sandia Corporation to Air Force Special Weapons Center, dtd 4/26/56, subject, Warhead Requirements for the GAM-63 Program. AEC Files, MRA-5, RASCAL, 7/55.

74. SRD Ltr, Field Command to Sandia Corporation, dtd 8/28/50, subject, REGULUS and RIGEL Guided Missiles. AEC Files, MRA-5, Vol. I, 1949-50.

75. SRD Ltr, Field Command to Sandia Corporation, dtd 11/29/50, subject, Design of Implosion Type Warhead for RIGEL Guided Missile. AEC Files, MRA-5, Vol. II, 10/50-6/51.

76. CRD Ltr, Field Command to Sandia Corporation, dtd 4/25/51, subject, RIGEL Missile Characteristics. AEC Files, MRA-5, RIGEL.

77. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 9/30/53, subject, Cancellation of the U. S. Navy Guided Missile Program, XW-5/RIGEL. AEC Files, MRA-5, 9/53-10/53.

78. SRD Ltr, Department of the Army to Sandia Weapons Development Board, dtd 3/13/51, subject, Assignment of Project to Ordnance Corps. SC Archives, microfilm reel MF-SF-SC-134.

79. SRD TWX, Division of Military Application to Sandia Corporation, dtd 5/21/51. SC Archives, microfilm reel MF-SF-SC-103.

80. SRD Ltr, Military Liaison Committee to Division of Military Application, dtd 6/4/51, subject, Atomic Warheads for Guided Missiles. AEC Files, MRA-5, HERMES.

81. CRD Ltr, Internal Sandia Corporation, dtd 5/27/52, subject, Time Scales for XW-5/HERMES A3BE1 Warhead Installation. SC Archives, microfilm reel MF-SF-SC-133.

82. CRD Ltr, Sandia Corporation to Field Command, dtd 6/9/52, subject, HERMES A3BE1 Nose Cone. AEC Files, MRA-5, HERMES.

83. CRD Ltr, Sandia Corporation to Sandia Field Office, AEC, dtd 6/11/52, subject, Estimated Complete Design Release Date for the XW-5/HERMES A3BE1 Warhead Installation. SC Archives, microfilm reel MF-SF-SC-135.

84. SRD Ltr, Sandia Corporation to Armed Forces Special Weapons Project, dtd 9/25/52, subject, HERMES A3BE1 Nose Cone. SC Central Technical Files, XW-5/HERMES.

85. SRD Ltr, Sandia Field Office, AEC, to Santa Fe Operations Office, dtd 10/27/52, subject, Delay in HERMES A3BE1 Program. SC Central Technical Files, XW-5/HERMES.

86. SRD Ltr, Field Command to Sandia Corporation, dtd 8/25/53, subject, HERMES A3BE1 Program Rescheduling. AEC Files, MRA-5, HERMES.

87. SRD Ltr, Division of Military Application to Santa Fe Operations Office, dtd 9/30/53, subject, HERMES A3BE1 Program. AEC Files, MRA-5, 9/53-10/53.

88. CRD Ltr, Sandia Corporation to Division of Military Application, dtd 4/18/53, subject, External Carriage of the Mark 5 Type Warhead. SC Archives, Transfer No. 45199.

89. SRD Ltr, Sandia Corporation to Distribution, dtd 8/3/53, subject, Status of the TX-5/F-101 Program. SC Central Technical Files, XW-5/F-101, 2-, 1953-7.

90. CRD Charter, XW-5/F-101 Joint Project Group, dtd 8/7/53. SC Archives, microfilm reel MF-SF-SC-1447.

91. SRD Minutes, XW-5/F-101 Joint Project Group to Distribution, dtd 7/20/54, subject, Minutes of 3rd Meeting. SC Central Technical Files, XW-5/F-101, 1-, 1953-6.

92. SRD Ltr, Sandia Corporation to Division of Military Application, dtd 5/24/55, subject, Application of Class C and D Thermonuclear Warheads in the F-101 Special Store Shape 96. SC Central Technical Files, XW-5/F-101, 1-, 1953-6.

93. CRD Ltr, Air Force Special Weapons Center to Sandia Corporation, dtd 6/10/55, subject, Application of Class C and D Thermonuclear Warheads in the F-101 Special Store Shape 96. SC Central Technical Files, XW-5/F-101, 1-, 1953-6.

94. SRD Ltr, Sandia Corporation to Distribution, dtd 3/5/56, subject, Cancellation of XW-5/XW-27/F-101 Programs. SC Central Technical Files, XW-5/F-101, 2-, 1953-7.

95. SRD Report, Sandia Corporation to Distribution, dtd 4/5/56, subject, XW-5/F-101 Informal Status Report. SC Central Technical Files, XW-5/F-101, 2-, 1953-7.